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ENVIRONMENTAL CONSIDERATIONS IN THE DEVELOPMENT OF THE ATOMIC ENERGY INDUSTRY

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This paper is one of a group given at Lehigh University and Lafayette College at Bethlehem and Easton, Pa., on October 22, 1954, at a special program of the City Planning Division in conjunction with the Lehigh Valley Section. It was designed to bring out the relationship between future commercial applications of the use of atomic fuel for developing power and city and regional planning.

The following papers comprise the program: "Elementary Principles of Nuclear Power" by John W. Landis, Customer Relations, Atomic Energy Div., The Babcock and Wilcox Co., New York, N. Y.,; "Prospects for Use of Nuclear Power" by H. W. Huntley, Member, Atomic Power Study, General Electric Co., Schenectady, N. Y.; "Impact of Atomic Development on Growth and Planning of Urban Regions" by Park H. Martin, M. ASCE, Executive Director, Allegheny Conference on Community Development, Pittsburgh, Pa.; "Environmental Considerations in the Development of the Atomic Energy Industry" by Arthur E. Gorman, M. ASCE, Sanitary Engineer, U. S. Atomic Energy Commission, Washington, D. C.; and "Local Government in the Atomic Age" by Harold A. Alderfer, Prof. of Political Science, Penn State Univ., State College, Pa.

These papers presented, first, the methods by which nuclear energy could be converted into power, reviewed the prospects for such power, and then took up: the effect that such atomic plants and the power which they would create might have on the future planning of metropolitan areas, the ways in which the public health might be protected against any harmful wastes, and, finally, the revisions in governmental structure that might be desirable as a result of the atomic age.

They pointed out that careful consideration should be given to site selection, both in consideration of adjoining developments and to assure safe disposal of radioactive wastes. Assurance was given that safe designs are within the realm of sound engineering. At the same time, it was pointed out that the potential new industry presents a challenge not only to engineers but to other scientists, private management, and public officials involved.

ENVIRONMENTAL CONSIDERATIONS IN THE DEVELOPMENT OF THE ATOMIC ENERGY INDUSTRY[1]

Arthur E. Gorman,* M. ASCE

As the atomic energy industry expands and goes forward under the liberalized Atomic Energy Act of 1954,(1) it will need, to an increasing degree, the advice and judgment of experienced civic planners. Competitive commercial enterprise has evidenced wide interest in the use of atomic energy and is rapidly acquiring knowledge of the industry and its potentialities. Since its consumptive markets are in the more populous areas of our Nation it is reasonable to assume that private industry will want to build its plants at places reasonably near these markets. A good example is the new AEC-Dusquene Light Company nuclear power plant being built near Shippingport, Pennsylvania, on the Ohio River about 37 miles downstream from Pittsburgh.

City planners and management of larger industries from which wastes in gaseous, solid and liquid state must be disposed of are well aware of the problems which a new or enlarged industry must face in protecting the health and safety of employees and in maintaining satisfactory environmental conditions in the communities in which they and others reside. The history of such industries as tanning, packing, coal mining, cement, pulp and paper making, by-product coke, and an array of other chemical processing and manufacturing industries reveals the problems encountered for lack of—and in some cases in spite of—advance planning in regard to waste disposal. In general, in those industries where advance planning had been carried out the impact of accidents or spills was reduced. Furthermore, plants which were well planned to take advantage of natural environmental assets experienced less difficulty with their neighbors and usually disposed of their wastes at lower cost than others.

The inevitable growth of the atomic energy industry into populous areas will present some interesting problems in waste disposal and environmental sanitation. This is known from experience with nuclear reactors, chemical processing plants and research laboratories now located in more or less isolated areas as at Hanford, Oak Ridge, Los Alamos and the National Reactor Testing Station in Idaho. Out of this experience, however, we are sure solutions of these problems can be arrived at, even though costs may be relatively high.

The purpose of this paper is to present to city planners some of the waste problems which exist in this new industry and to indicate where we stand in resolving them; also to point out areas for cooperation between the industry and public health, safety and planning officials.

Responsibilities of New Industry

On reading the new Atomic Energy Act of 1954 one cannot help but be

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1. To be read at meeting of the City Planning Division, American Society of Civil Engineers at Lehigh University, Friday, October 22, 1954.

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impressed by the fact that the phrase "to protect (or affect) the health and safety of the public" occurs seventeen times. This reflects the desire and intent of the Congress to make sure that in its liberalized expansion the industry does not create hazards which would endanger lives and property. Based on present knowledge and experience there is reason to believe that this can be accomplished.

A responsibility of more than average depth rests with all who invest and work in the atomic energy industry to make sure that the spirit and intent of the Act as affecting public health and safety are carried out. For one thing, the characteristics of radioactive wastes released from the atomic energy industry are such that a considerable amount of deception could in fact be practised. As an example, a tall stack from a reactor of a chemical processing plant could release highly radioactive gases and particulates yet never show a trace of gaseous effluent being discharged. Large volumes of colorless, odorless and high radioactive liquid wastes could be released to a nearby stream without attracting attention by normal pollution indices, such as physical appearance, odor, biochemical oxygen demand or suspended solids.

By comparison with most other industries the costs of disposal of wastes from the atomic energy industry are high—much higher than is generally realized. It is therefore, conceivable that in certain circumstances a temptation might arise to take chances or to cut corners. Nothing could be more harmful than loss of public confidence at a time when the new industry is experiencing its growing pains. It has occurred however, to other industries.

Public Officials Uninformed

An exceedingly important consideration is the fact that as yet officials of most public regulatory agencies outside the atomic energy industry are not too well informed as to the materials, the technology, the waste products, the terms and the standards of this industry. I am happy to report that this situation is being corrected at an accelerating rate. This is being accomplished through training courses offered by the Atomic Energy Commission at its national laboratories and by the Public Health Service at the Robert A. Taft Sanitary Engineering Center at Cincinnati; also through seminars and forums sponsored by several universities and private agencies. In addition, advisory committees have been organized by AEC managers at the Hanford Works, the Knolls Atomic Laboratory and at the National Reactor Testing Station in Idaho.

A period of many years may pass however, before public regulatory agencies in the fields of public health, safety, and conservation will be in a position to understand the operations of the atomic energy industry to the degree they are now informed as to the environmental hazards of waste disposal associated with the more orthodox industries. Through cooperation and candor with these public officials supported by continued research of the type now in progress it should be possible to demonstrate that this new industry can go forward without having to be handicapped by unfair and punitive laws and regulations. In the years immediately ahead the industry's performance and the attitude of management of companies which elect to use nuclear energy will do much to establish the pattern of public controls which will be exercised.

Waste Disposal Needs Special Attention

Newcomers to the atomic energy industry will want to give special consideration to disposal of wastes and waste products and the potential environmental problems resulting from their release. Industrial teams that have studied the industry to date may not have given disposal of its wastes the

attention it deserves from the standpoint of costs and public relations. It is understandable that their interest may have been centered on the more fascinating areas of reactor technology and evaluation of commercial possibilities in the use and application of atomic energy. But it would be a great disservice to their sponsors if they fail to face the backdoor realities of planning and operating a nuclear reactor or chemical processing plant.

The problem of integrating the new atomic energy industry into the national industrial and community complex rests in no small degree on our ability to live with radiation without damage to life and property. It is complicated because radioactivity is known to damage living cells depending on the type, intensity and duration of exposure and because certain radioactive materials have very long half lives.(2) We have learned to live with automobiles, gasoline, and high explosives for the reason we have learned to control them and to minimize their hazard potential. Radiation controls must be rigid and in certain cases of long duration. Decisions on disposal of radioactive material call for the best judgments of experts in the effects of radiation, the chemical properties of the isotopes concerned, the characteristics of the wastes as released and their ultimate fate in nature depending on whether release is to the air, the ground, or to surface waterways. We are indeed our brothers keepers.

Sources of Wastes

Control over the wastes of the atomic energy industry logically starts with the mining of the radioactive ores and continues on with the handling, transportation, crushing, and sieving processes. Even though the specific activity of these materials is not high, good housekeeping is required in order to protect workers from uranium-bearing dusts and exposure to radon which is given off in decay of uranium. The several chemical treatments which follow for enrichment result in production of long-lived radioactive sludges which are stored.

Gaseous effluents are decontaminated by scrubbers, separators and filters of various kinds. In the subsequent metallurgical, machining, extruding or complexing of the fuels with other materials, wastes result—most of which are reclaimed for reprocessing.

Many of the operations in process up to assembly of fuel elements are similar to those in other industries and wastes are susceptible to treatments used in other metal and chemical industries. But there are variations in stream loadings which must be taken into consideration especially in decontamination of air streams where often orthodox facilities are not adequate.

The more acute problems in waste disposal from the industry start after the fuel elements are irradiated in the reactors especially those in continuous production, or test runs. New developments in reactor fuels and assemblies present new problems in chemical processing and waste disposal. It is of the greatest importance that research and development in these closely related technological fields go forward together.

Today after ten years of extensive research and development the industry has no completely satisfactory method of disposal of high level radioactive wastes. These wastes may contain several hundred curies per gallon. Their safe disposal is a must item. The costs of current methods are many times greater than in most other industries. They are much higher than could be tolerated continually in a highly competitive field. The cost and disposal of radioactive wastes are matters which industrial users of atomic energy must evaluate with great care or they will arise to plague them.

From the standpoint of environmental hazards the problems of high-level radioactivity in product and wastes at nuclear reactors and chemical plants for processing irradiated fuels need evaluation under two considerations. One is, what exposures would follow a gross accident in which all or a part of the total curies of radioactivity in the plant is released to the environment. The other is the exposures resulting from the normal day-to-day release of wastes to the atmosphere, to the ground or into surface waterways.

Realization of Hazards

Evaluation of the hazards of a potential catastrophe is very complicated and requires judgment from many specialists. It is important that a broad spectrum of competency be brought to bear on this type of hazard. The environmental specialists, such as meteorologists, hydrologists, biologists, and geologists should have a good understanding of the type and characteristics of the radioactive contaminants which would be released. In the public interest pessimistic rather than optimistic conditions should be assumed. The history of recent calamities in industry such as the Texas City, Texas (April 1947) and the Port of South Perth Amboy, New Jersey, explosions (May 1950) and the General Motors Fire at Livonia, Michigan, (August 1953) support this position.

Site Selection

The possibility of a catastrophic accident, regardless of origin, is one of the important considerations in selecting a site for a reactor, a chemical processing plant, or a research and development laboratory using high levels of radioactivity. The environmental considerations as to a site for a plant at which atomic energy will be used are perhaps more important than for any other industry. Penalities in future plant operations and in additional costs of waste treatment and disposal facilities could result from inadequate information as to site meteorology, geology, hydrology, water supply sources and the time and distance of travel of wastes to other industries and population areas.

Transport of Radioactive Materials

The transport of irradiated fuels from the reactor to the chemical processing plants requires special consideration to assure safety. As more reactors are built near populated areas distant from chemical processing plants there will be more shipments of irradiated fuels and additional problems of shielding, transport and control. If highly radioactive wastes are shipped from chemical plants to places of disposal, a similar problem is presented. Routes of travel are selected to avoid hazards of exposure in case of an accident. Shielding requirements result in heavy loadings for relatively small volumes of high level fuel or wastes. Under these conditions cost of transport is necessarily high. These realities may have a profound influence on the location of future chemical processing plants.

Waste Disposal Policy

Policy in waste disposal must rest on the extent of knowledge and understanding of two major factors: first, the limits of radioactive contamination by the various isotopes in air, water and foods which man can tolerate over a life time or for shorter periods. Recommended limits are given in National Bureau of Standards Handbook 52.[4] Second, the dilution factors in nature

which can be taken advantage of with assurance that these permissible limits will not be exceeded. Currently determination of these factors is the basis of much research sponsored by AEC.

With these two parameters established it is possible to ascertain the degree to which wastes must be treated and also the conditions under which waste effluents may be released to nature or be retained in storage under controlled conditions. Recently a draft of policy in waste disposal to be followed by AEC contractors at all installations was discussed with representatives of state and federal regulatory agencies. Early promulgation of policy and limits of activity to be met in release of wastes is expected.

It is important to confine radioactivity to as few areas as possible and to remove waste materials from process streams near their point of origin. This permits dealing with the wastes in minimum volume. Allowing wastes to become intermingled with larger process or waste streams will add materially to the cost of cleanup. These are principals of good practice in most industrial operations.

Liquid Wastes

Wet extraction or separation methods result in substantial volumes of both toxic and radioactive liquid wastes and gaseous effluents. Treatments for separating fission products from unburned fuel, for decontamination and recovery of solvents and for reduction in volume of wastes are costly. The extent to which decontamination should be provided is directly related to the degree to which radioactivity in the waste streams can be made innocuous for storage or be diluted to safe levels by release to the environment.

Gaseous Wastes

Gaseous effluents from reactors and chemical separation plants are usually released through lined stacks from 200 to 250 feet high. Decontamination of these effluents prior to release requires costly scrubbing, extraction, and filtering facilities. Where weather conditions are favorable or if operations can be arranged so release can be made at such periods substantial savings can be made in decontamination.

Air cleaning facilities of all types are used in the industry for removing dust, mists, fumes, and radioactive gases of various kinds. High levels of radioactivity are frequently associated with particulates of micron and submicron sizes. It is essential that stream loading be known in order that proper air cleaning facilities may be selected—otherwise removal efficiencies may be low.

A working group of consultants was appointed in 1948 to assist in the problem of area contamination by radioactive particulates from stacks. On their recommendation an air cleaning testing laboratory was equipped in Boston under contract with the Department of Industrial Hygiene, Harvard School of Public Health. Staff of that laboratory has tested all kinds of air cleaning facilities used in the industry and has helped manufacturers make changes in orthodox equipment in order to meet special requirements in dealing with radioactive waste streams. Its staff has prepared a handbook[5] on air cleaning which is in wide circulation.

There was urgent need of an efficient air filter which would remove submicron radioactive particles from effluent air streams. Under AEC contact the A. D. Little Company[6] has developed high efficiency air filters for use in the industry operable at temperatures as high as 600° F. Filter media for

temperatures less than 275° F. are of Kraft paper and asbestos; for higher temperatures media of glass fiber and asbestos or all glass fibers are used. Removal efficiencies are 99.95 percent for 0.3 micron particulates.

At the Hanford Works a stack gas problem involving radioactive effluents in large volumes was met successfully by the construction of a deep bed sand filter. Later research has demonstrated the effectiveness of deep bed filters using fiber glass as the filter medium.

Storage of Radioactive Wastes in Tanks

Within the industry tens of millions of gallons of high level radioactive wastes are stored in steel or steel and concrete tanks. Present locations of these tanks are in isolated areas in soils through which movement in case of leakage would be slow. There is frequent monitoring to detect any leaks.

The storage of hazardous radioactive wastes having a half life of hundreds or thousands of years in tanks having a probable life of several decades is not considered adequate ultimate disposal of these wastes. It is in fact an expediency which for lack of a better method has been followed.

Storage of radioactive wastes in underground tanks is costly. Currently costs for tank storage vary from $0.35 to $2.00 per gallon. In addition there is the continuing cost of monitoring and cooling as required.

Fixation on Solids

A method of fixation of high level radioactive liquid wastes in a solid media from which they cannot be leached by submersion in active acids, alkalies and sea water, has reached the pilot plant stage at the Brookhaven National Laboratory.(7) The process consists of absorption on montmorillonite clay prepared in the form of pellets in order to reduce resistance to flow in columns through which liquid radioactive wastes are passed. After saturation the pellets are heated to 800° C. to form hard ceramic beads. When locked up in this solid form the wastes may be stored in or above ground with no loss of activity other than that caused by natural radioactive decay. This will not be an inexpensive process, but costs are expected to be well within the range given above for tank storage.

Burial of Wastes

The whole problem of ultimate disposal of radioactive wastes is due for a review as the industry moves toward more populated areas. Disposal by burial in the ground has been advocated and is under investigation. This method has been practised extensively for low and intermediate level wastes where problems of heat generated by nuclear activity are not encountered. The site of a burial ground should be selected by an experienced geologists and only after data have been collected as to the characteristics of the retaining soils and those in lower strata, the direction and rate of movement of the wastes through these soils and the flow time and distance to downstream users of ground water.

Absorption of Soils

It has been found that a number of soils especially the clays have capacity to adsorb or absorb many radioactive isotopes. But this is not true of all isotopes. The ability of soils to absorb wastes of low and intermediate levels is being taken advantage of in many areas.

The More Hazardous Isotopes

Strontium 90 with a half life of 25 years and the property of depositing in bone structure is an especially hazardous component of fission product waste. There are also several others. Serious consideration is being given to means of removing these significant and hazardous isotopes from waste streams which could then be released to the environment. If this could be accomplished much less stringent requirements as to release of wastes to the ground and surface waters would be possible.

Disposal into Deep Wells

Disposal of high level radioactive wastes to natural or man-made cavities at the bottom of deep wells in areas where natural resources would not be jeopardized offers some possibilities provided the wells are at or near chemical processing plants. The potentialities and limitations of this method are being investigated.

Disposal to the Oceans

The vastness of the oceans suggests that high level radioactive wastes might be disposed of in selected areas where dilution is great and conditions are favorable for a slow rate of release. For several years ocean disposal has been carried out on a limited basis in the Atlantic and Pacific in waters 500 to 1000 fathoms deep. The wastes have been enmeshed in concrete in steel oil drums. Cost, including packaging, handling, and disposal, vary from $0.30 to $1.00 per pound. Under present practices land burial is by far the cheaper method, especially for inland site. It requires less preparation for shipment and shorter hauls to burial grounds than to dockside.

Disposal to Surface Waterways

The ability of surface waterways to take up and dilute radioactive wastes is a phenomenon which will be reflected in costs of waste treatments and the attitude of public officials concerning the use of these waterways for disposal of wastes. Through a cooperative program staff of the Knolls Atomic Laboratory (KAPL), the Geological Survey, the Department of Health of New York and the Harvard University have made two field tests to determine the fate of radioactivity released from KAPL to the Mohawk River. During the last test in August, 5 curies of phosphorus 32 were released and its fate in the river studied by special teams from these agencies. A vast amount of knowledge as to the fate of radioactivity in reactor cooling water released to the Columbia River from the Hanford Works has been obtained by staff of the General Electric Company and the Public Health Service.

Cooperation with Federal Agencies

As the atomic energy industry goes forward newcomers should be able to avoid many of the mistakes which other new industries have experienced in the past in disposal of wastes. Staff of AEC has sought the aid of a wide range of specialists in evaluating its problems of waste disposal and environmental sanitation. Many of these specialists are the same with whom any alert public planning organization would consult in working with industry in the selection of a plant site and in developing an understanding as to disposal of wastes of all kinds.

Staff of the Geological Survey have visited all major AEC areas and have assisted in evaluating the effect of disposing wastes to the ground. They have studied the soils and their characteristics in relation to the migration of wastes and possible future effect on ground water supplies. They have assisted in the selection of burial grounds for wastes. They have advised as to the availability of ground water supplies and have served in a consulting capacity in selection of plant sites and the location of specific buildings and facilities at these sites. Within this federal agency there has developed an understanding of the industry's problems and a competency in evaluating them. This will permit its staff to serve in an impartial way both the interest of public in protecting natural resources and industry in its march forward.

In a similar way staff of the Weather Bureau have come to understand the problems of release of gaseous waste effluents from atomic energy plants. Meteorologists have visited most AEC installations and reported on meteorological conditions of special significance. In the cases of Oak Ridge, Brookhaven and the National Reactor Testing Station, Weather Bureau meteorologists have studied in great detail the atmospheric phenomena of these areas and have given very constructive advice as to plant locations and waste disposal. This has included evaluation of opportunities and limitations for taking advantage of meteorological conditions in normal and abnormal plant operations. A handbook on meteorology for use in the atomic energy industry is in preparation by staff of the agency.

The Combustion Research Laboratory of the Bureau of Mines under contract with AEC has developed an incinerator[8] for institutional (25 lb/hr) and for plant (200 lb/hr) use. Detail plans and specifications are in preparation and it is planned to make them available to any one interested in fabricating these units. The volume of combustible radioactive wastes of various levels of radioactivity which result from production and research activities within the industry is high and there is need for an efficient incinerator which could be manufactured and operated at moderate costs. These BUAEC incinerators, as they have been named, use tangentional overfeed air supply in the combustion chamber. This results in a high degree of burnup so that the products of combustion can be removed in an inertial type separator followed by a high-efficiency high-temperature filter.

The Public Health Service staff both in Washington and at the Robert A. Taft Sanitary Engineering Laboratory in Cincinnati have cooperated actively with the AEC in evaluating problems of disposal of radioactive and toxic wastes, in methods of decontamination of radioactive wastes, in air cleaning and in studying the chemical, biological and radiological characteristics of rivers used as sources of water supply or for disposal of wastes. This agency has well established relations with state and local health departments, interstate commissions regulating stream pollution and professional societies in the fields of public health and engineering. It is a particularly good position to serve all who are interested in using atomic energy or in evaluating the impact on the environment of the operations of this industry and the resulting wastes. Its continuing programs for training public officials in the fundamental of nuclear science especially as related to public health and environmental sanitation have been of outstanding service to the industry and of great public value.

Research and Development at Universities[9]

Time does not permit a detailed discussion of the large amount of research

and development work which has been carried out under contract with AEC at various universities and private research institutions to assist in evaluating problems in waste disposal and developing means of resolving them. These contracts are for unclassified work and for the most part the results have been published in technical journals which serve the water works, sewage and industrial wastes and public health engineering fields. At the various universities these research programs served to stimulate the interest of graduate students to work with radioactive materials and to take special courses in nuclear sciences. Several of these research associates are now employed in the industry using radioactive tracers as tools for accomplishing results by simple and direct methods. The interest of undergraduate and graduate students in the atomic energy industry has already had its effect on the teaching of nuclear science at colleges and universities.

Public Regulatory Agencies

In the United States there has developed over the years a close and effective working relationship between federal, state, and local agencies. In close cooperation with the Public Health Service such organizations as the Conference of State Sanitary Engineers have for many years met regularly to discuss items of mutual interest and concern and have been successful in formulating broad policies and procedures which are accepted throughout the nation. They have a long record of service and cooperation with industry. Under the federal stream pollution act of 1945 (Public Law 845) special research and development committees have been organized to assist industries and municipalities in resolving problems of waste treatment and disposal.

In most states permits for disposal of wastes from industries to waterways and to the ground must be obtained from sanitary engineering divisions of state departments of health or water resources commissions on which public health and conservation departments are represented. The interstate aspects of stream pollution are dealt with in various sections of the nation by formal agreements between states under compacts approved by the Congress or more informal agreements between state departments of health.

In addition, under treaty agreements between the United States and Canada and the United States and Mexico commissions exist for discussions of international problems, including pollution of international water and airways. These are the International Joint Commission (Canada and United States) and the International Boundary Commission for the Rio Grande (Mexico and United States).

CONCLUSIONS

As the atomic energy industry goes forward under the liberalized provisions of the Act of 1954, it is to be expected that commercial users will want to build plants near centers of population where markets exist for their product. Since radioactive wastes have properties which are hazardous, much care must be exercised in release of radioactive wastes from these plants. This will call for careful advance planning of sites, the location of plants on-site with relation to one another and their facilities and evaluation of environmental factors such as meteorology, geology, and hydrology.

In anticipation of certain environmental problems in this new industry in regard to release of wastes, the atomic Energy Commission has sought through the cooperation of other federal agencies, its operating contractors

and through research and development contracts with universities and private research agencies to evaluate the effect of operations at its own plants and thereby be in a position to help new private users of nuclear energy as they enter the field in the more populated areas.

This new industry and the direction of its future growth will present many problems and offer an intriguing challenge to private management, scientists, engineers and public health, planning and conservation officials.

Through continued cooperation between AEC, industrial management and staff of public regulatory agencies the new atomic energy industry can become well integrated in the national economy without encountering the many difficulties which other industries have experienced. The civic planner could well be a most important influence in bringing this situation to reality.

LITERATURE CITED

1. Public Law 703 - 83rd Congress.
2. Mechanics Vol. 12 - No. 9 - Sept. 1954 - p 66.
3. Handling Radioactive Wastes in the Atomic Energy Industry, Bulletin, US AEC Washington (25) D. C. 1951.
4. National Bureau of Standards Handbook 52, Supt. of Documents Washington (25), D. C.
5. Handbook on Air Cleaning - AEC, S. K. Friedlander, et al, Supt. of Documents, Washington (25) D. C. 1952.
6. "Development of High Temperature - High Efficiency Air Filter" Summary Report to AEC, A. D. Little, Inc., Aug. 1953.
7. "Ultimate Disposal of Radioactive Wastes" L. P. Hatch American Scientist, Vol. 41, July 1953, pp 410-421.
8. "Experimental Study of Effects on Tangential Orifice of Air in Incinerators," R. C. Corey, Air Pollution Control Assoc. Baltimore, Md., May 26, 1952.
9. Major Activities of the Atomic Energy Programs, July - Dec. 1953 - U. S. Government Printing Office - 1954, Washington 25, D. C.